Plasma Processing
Room Naupaka Salon 1-3 - Session PS-TuP

Plasma Processing Poster Session
Moderator: Martin Nieto-Perez, CICATA Queretaro

PS-TuP2 Study of Carbon Fiber Manufacturing Process by Plasma Oxidation/stabilization and Microwave assisted Carbonization, ***Seok-Kyun Song***, *B.Y. Kim, M.K. Jung,* Cheorwon Plasma Research Institute, Republic of Korea*; S. Lee,* Korea Institute of Science and Technology, Republic of Korea

Carbon fiber has a carbon content of 90~95% or more, and its strength is ten times that of steel. The manufacturing process proceeds with stabilization (chlorination), carbonization of the PAN fiber. In particular, the stabilization process is long-term treatment at high temperature which high cost is incurred. In order to low cost manufacture for carbon fiber, that is need reduction of stabilization process time. For that, we researched the oxidation/stabilization process using atmospheric pressure plasma and e-beam technology.

The atmospheric pressure plasma system developed by CPRI team suggests possibility to reduce oxidation/stabilization process time (from 120 min to 30 min, from 120 min to 10 min by add e-beam technology) and cost. Plasma oxygen radical accelerates the progress of fiber cyclization. After plasma treatment, the surface of oxidized/stabilized fiber had no damage.

In the nitrogen atmosphere, oxidated/stabilized fiber was used for low temperature carbonization of 300 ~ 1000 degrees Celsius, and energy consumption was reduced by directly supplying energy to the heating element near the fiber by the microwave assisted (MWA) method instead of the conventional resistance heating.

It has been suggested that energy can also be reduced by providing microwave assisted (MWA) energy directly to low temperature carbonized fiber for 1000 ~ 1600 degree Celsius high temperature carbonization.

PS-TuP4 Nitridation of SiO_2 by using a VHF (162 MHz) Multi-tile Push-pull Plasma Source, ***You Jin Ji***, *K.S. Kim, K.H. Kim, J.Y. Byun, S.J. Lee,* Sungkyunkwan University, Republic of Korea*; A.R. Ellingboe,* Dublin City University, Ireland*; G.Y. Yeom,* Sungkyunkwan University, Republic of Korea

Nitriding processes of SiO_2 thin film have been applied in various semiconductor device manufacturing. For example, in the fabrication of nanometer scale semiconductor devices, a nitriding process of SiO_2 for a nitride layer applied to gate insulator has become an important process to prevent the penetration of p-type dopant (boron) through the thin gate oxide. Typically, plasma and thermal nitridation methods are used to meet the requirement for the nitride layer. However, the thermal method has a bad influence on the device performance due to the high processing temperatures (600-1500 °C), and the plasma method tends to cause damage on the treated layer due to the ion bombardment and shows a low nitridation percentage in the film due to the difficulty in dissociating nitrogen molecules having a high electron-impact dissociation energy. Very high frequency (VHF; > 30 MHz) plasma is known to dissociate nitrogen molecules more effectively with a high dissociation rate at a low temperature due to a high electron energy tail in the electron energy distribution. Therefore, in this study, the nitridation of SiO_2 was performed to obtain a uniform silicon oxynitride (SiO_xN_y) layer using a VHF (162 MHz) multi-tile push-pull plasma source at room temperature. High nitrogen incorporation (~ 24.51 %) in the SiO_xN_y layer was confirmed by the X-ray photoelectron spectroscopy (XPS) analysis at the optimized nitridation condition. In addition, the EDS in TEM showed that a SiO_xN_y layer was uniformly formed after the nitridation of SiO_2 at the optimized condition. The leakage current of the MOS capacitor that has the SiO_xN_y layer formed by using the VHF (162 MHz) multi-tile push-pull plasma source was measured to be lower than that has the SiO_xN_y layer formed by the conventional CCP (60 MHz) plasma source.

PS-TuP5 ***Fabrication of SnO Thin Films by Reducing Plasma on Atomic Layer Deposited SnO_2***, ***Jaehong PARK***, *B.E. PARK, H.J. Kim,* Yonsei University, Republic of Korea

Oxide semiconductors have been intensively investigated in emerging applications, such as thin film transistor (TFT), flexible electronics and solar cell materials, owing to the added functionality using great diversity of materials and structures. There have been numerous studies on n-type semiconductors such as ZnO, SnO_2, and In_2O_3, whereas the research on p-type semiconductors is still ongoing due to the lack of synthesis technology. SnO is a representative p-type oxide semiconductor with wide band-gap and high mobility, but the poor stability of SnO limits the synthesis method to physical vapor deposition (PVD). PVD is difficult to apply in future integrated circuit process with aggressive scaling down and 3D structurization. Atomic layer deposition (ALD) is a promising technique owing to atomic-scale thickness controllability and great conformality. In this study, we synthesized p-type SnO thin film using ALD and consequent plasma treatment for reduction. We investigated the crystal structure, morphology, and electrical properties of SnO by using x-ray diffraction (XRD) and atomic force microscope (AFM). In addition, we evaluated the thermal and chemical stability of SnO film. As a result, SnO film shows highly stable SnO phase even after annealing at 400 °C with oxidation/reduction environment. This study will contribute to apply oxide semiconductor in future application by implementing various device structure, such as p-n junction, complementary metal oxide semiconductor(CMOS), and p-channel TFT.

PS-TuP6 Plasma-Surface Interactions in Atmospheric Pressure Plasmas: In situ Measurements of Electron Heating in Materials, *S. Walton,* Naval Research Laboratory*; B. Foley,* Pennsylvania State University*; J. Tomko,* University of Virginia*; D.R. Boris, E.D. Gillman, S.C. Hernandez,* Naval Research Laboratory*; A. Giri,* University of Virginia*; T.B. Petrova,* Naval Research Laboratory*;* ***Patrick Hopkins***, University of Virginia

The energy flux to a surface during plasma exposure and the associated surface heating are of long standing interest as they contribute to the physico-chemical changes that occur during plasma-based materials synthesis and processing. Indeed, the energy delivered to the surface, via a flux of particles and photons, in concert with a flux of reactive species serves to chemically modify, etch, and/or deposit materials, with an efficacy that depends on the plasma processing environment. A unique feature of plasma synthesis and processing is that most of the delivered energy is absorbed at or very near the surface over short (picosecond) time scales. The dissipation of thermal energy proceeds through electron-electron and/or electron-phonon interactions as they propagate through the material, with relaxation time scales that can be orders of magnitude slower. Typically then, the surface is not in thermal equilibrium with the bulk material. Fast, surface-sensitive techniques are thus required to fully appreciate the dynamics of the plasma-surface interaction. In this work, we employ pump-probe Time-Domain Thermoreflectance, a surface sensitive technique typically used to measure thermal properties of thin films, to determine electron heating of thin metal films during exposure to an atmospheric pressure plasma jet. The results, in conjunction with current measurements, are used to develop a first order understanding of plasma jet-surface interactions. The results show that the energy delivered by the plasma jet causes a localized increase in electron energy within the thin film over an area commensurate with the plasma jet radius. More details of this work an be found in the following recently published paper: Walton, S.G., Foley, B.M., Tomko, J., Boris, D.R., Gillman, E.D., Hernandez, S.C., Giri, A., Petrova, Tz.B., Hopkins, P.E., "Plasma-surface interactions in atmospheric pressure plasmas: In situ measurements of electron heating in materials," *Journal of Applied Physics* **124**, 043301 (2018).

PS-TuP9 Origin of Plasma Damage during Sputtering of Ultrathin ITO Contact Layer on p-GaN for InGaN/GaN LEDs, *T.K. Kim, Y.-J. Cha,* ***Joon Seop Kwak***, Sunchon National University, Republic of Korea

We systematically examined the origin of plasma-induced damage on *p*-GaN surface during the sputtering of ITO transparent conductive electrodes (TCE) and its effects on the forward voltage and the light output power (LOP) of InGaN/GaN LEDs. Firstly, we investigated the effect of direct current (DC) power in radio frequency (rf) superimposed DC sputtering (RF+DC sputtering) of ITO on the forward voltage and and LOP of InGaN/GaN LEDs and found that the plasma-induced damage was sensitive to the DC power. The forward voltages of the LEDs at 20 mA drastically decreased from over 5 V to 3 V and the LOP of the LEDs was greatly enhanced by more than 20% at 250 mA, when the DC power was changed from negative to positive values. Secondly, electron flux as well as ion flux during the RF+DC sputtering of ITO with the various DC power were calculated based upon the plasma discharge parameters measured by cutoff probe and Langmuir probe. Changing the DC to positive power drastically reduced the electron flux in plasma, suggesting that plasma electrons play an important role in plasma-induced damage of *p*-GaN surface. Furthermore, the significant increase in forward voltage of the LEDs was observed, when electron-beam irradiation on *p*-GaN surface was employed. This confirms that the plasma electrons, not ions, can cause the plasma-induced damage on *p*-GaN during the sputtering of ITO. Lastly, physical mechanism for the generation of plasma-induced damage on *p*-GaN by the plasma electrons was suggested. The plasma electrons can

compensate the deep level defects (DLDs) in the *p*-GaN surface and reduce the density of DLDs, which increase the effective barrier height at the ITO/DLD band of *p*-GaN. Furthermore, the plasma electrons yielded the energetic ad-atoms of ITO on *p*-GaN during sputtering by energy transfer of the electrons to the ad-atoms and increased the plasma-induced damage on *p*-GaN. We successfully demonstrated the plasma-induced-damage-free ITO TCE on the InGaN/GaN LEDs by sputtering, which showed 20 % improved LOP of the LEDs with comparable forward voltage of 2.9 V at 20 mA to the LEDs with conventional e-beam-evaporated ITO.

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